

WHAT IS CLAIMED IS:

1 1. A hearing aid, comprising:
2 an input signal channel providing digital input signals;
3 a signal path adapted to process said digital input signals in accordance
4 with a predetermined signal processing algorithm to produce a digital output signal,
5 wherein said signal path further comprises at least one signal processing function
6 operating on a warped frequency scale; and
7 an output conversion means adapted to convert said output signals to an
8 audio output.

1 2. The hearing aid of claim 1, wherein said at least one signal
2 processing function further comprises a plurality of cascaded all-pass filters.

1 3. The hearing aid of claim 1, wherein said warped frequency scale
2 approximates a Bark scale.

1 4. A dynamic range compressor, comprising:
2 an input signal channel providing digital input signals;
3 a plurality of cascaded all-pass filters, wherein said digital input signals
4 pass through said plurality of cascaded all-pass filters, and wherein said plurality of
5 cascaded all-pass filters output a sequence of delayed samples;
6 means for applying a frequency domain transform on said sequence of
7 delayed samples, wherein a warped sequence results from said frequency domain
8 transform applying means;
9 means for calculating a plurality of frequency domain level estimates from
10 said warped sequence;
11 means for calculating a plurality of frequency domain gain coefficients
12 from said plurality of frequency domain level estimates;
13 means for applying an inverse frequency domain transform on said
14 plurality of frequency domain gain coefficients, wherein a set of compression filter
15 coefficients of a compression gain filter result from said inverse frequency domain
16 transform applying means; and

17 means for convolving said sequence of delayed samples with said set of
18 compression filter coefficients to produce a digital output signal.

1 5. The dynamic range compressor of claim 4, further comprising a
2 hearing aid, wherein the dynamic range compressor is incorporated within said hearing
3 aid.

1 6. The dynamic range compressor of claim 4, wherein said plurality
2 of frequency domain gain coefficients comprise a warped time-domain filter.

1 7. The dynamic range compressor of claim 4, further comprising
2 means for windowing said sequence of delayed samples, wherein a windowed sequence
3 of delayed samples results from said windowing means, and wherein said warped
4 sequence results from applying said frequency domain transform to said windowed
5 sequence of delayed samples.

1 8. The dynamic range compressor of claim 4, further comprising a
2 digital-to-analog converter, said digital-to-analog converter converting said digital output
3 signals to analog output signals.

1 9. The dynamic range compressor of claim 8, further comprising an
2 output transducer, said output transducer converting said analog output signals to an
3 audio output.

1 A 10. The dynamic range compressor of claim 4, said plurality of
2 cascaded all-pass filters comprising a plurality of first order all-pass filters.

1 11. The dynamic range compressor of claim 4, said sequence of
2 delayed samples comprising 16 samples.

1 12. The dynamic range compressor of claim 4, further comprising a
2 digital processor, wherein said digital processor is adapted to provide said frequency
3 domain transform applying means, said frequency domain level estimates calculating
4 means, said frequency domain gain coefficients calculating means, said inverse frequency
5 domain transform applying means, and said means for convolving said sequence of
6 delayed samples.

1 13. The dynamic range compressor of claim 12, wherein said digital
2 processor comprises a software programmable digital signal processor.

1 14. The dynamic range compressor of claim 4, wherein said frequency
2 domain transform applying means uses a transform selected from the group consisting of
3 discrete Fourier transforms, fast Fourier transforms, Goertzel transforms, and discrete
4 cosine transforms.

1 15. The dynamic range compressor of claim 4, further comprising:
2 an input transducer, said input transducer converting audio input signals to
3 analog input signals; and
4 an analog-to-digital converter, said analog-to-digital converter converting
5 said analog input signals to said digital input signals.

1 16. The dynamic range compressor of claim 4, further comprising:
2 a digital-to-analog converter, said digital-to-analog converter converting
3 said digital output signals to analog output signals; and
4 an output transducer, said output transducer converting said analog output
5 signals to an audio output.

1 17. A dynamic range compressor, comprising:
2 an input signal channel providing digital input signals;
3 an input data buffer, said input data buffer holding at least one block of
4 data comprised of a portion of said digital input signals;
5 a plurality of cascaded all-pass filters, wherein a first block of said digital
6 input signals pass from said input data buffer through said plurality of cascaded all-pass
7 filters, and wherein said plurality of cascaded all-pass filters output a first sequence of
8 delayed samples;
9 means for windowing a first portion of said first sequence of delayed
10 samples, wherein a first windowed sequence of delayed samples results from said
11 windowing means;
12 means for applying a first frequency domain transform on said first
13 windowed sequence of delayed samples, wherein a first warped sequence results from
14 said first frequency domain transform applying means;

means for calculating a first plurality of frequency domain level estimates of said first warped sequence;

means for windowing a second portion of said first sequence of delayed samples, wherein a second windowed sequence of delayed samples results from said windowing means;

means for applying a second frequency domain transform on said second windowed sequence of delayed samples, wherein a second warped sequence results from said second frequency domain transform applying means;

means for calculating a second plurality of frequency domain level estimates of said second warped sequence;

means for summing said first and second plurality of frequency domain level estimates, wherein a summed first and second plurality of frequency domain level estimates results from said summing means;

means for normalizing said summed first and second plurality of frequency domain level estimates, wherein a normalized first and second plurality of frequency domain level estimates results from said normalizing means;

means for calculating a plurality of frequency domain gain coefficients from said normalized first and second plurality of frequency domain level estimates;

means for applying an inverse frequency domain transform on said plurality of frequency domain gain coefficients, wherein a set of compression filter coefficients of a compression gain filter result from said inverse frequency domain transform applying means;

means for convolving a second sequence of delayed samples with said compression filter coefficients, said second sequence of delayed samples produced by a second block of said digital input signals passing from said input data buffer through said plurality of cascaded all-pass filters, wherein a digital output signal results from said convolving means.

18. The dynamic range compressor of claim 17, further comprising a hearing aid, wherein the dynamic range compressor is incorporated within said hearing aid.

19. The dynamic range compressor of claim 17, wherein said plurality of frequency domain gain coefficients comprise a warped time-domain filter.

1 20. The dynamic range compressor of claim 17, further comprising a
2 digital-to-analog converter, said digital-to-analog converter converting said digital output
3 signals to analog output signals.

1 21. The dynamic range compressor of claim 20, further comprising an
2 output transducer, said output transducer converting said analog output signals to an
3 audio output.

1 22. The dynamic range compressor of claim 17, said plurality of
2 cascaded all-pass filters comprising a plurality of first order all-pass filters.

1 23. The dynamic range compressor of claim 17, further comprising a
2 digital processor, wherein said digital processor is adapted to provide said windowing
3 means, said means for applying said first and second frequency domain transforms, said
4 means for calculating said first and second plurality of frequency domain level estimates,
5 said summing means, said normalizing means, said frequency domain gain coefficients
6 calculating means, said inverse frequency domain transform applying means, and said
7 convolving means.

1 24. The dynamic range compressor of claim 17, wherein said means
2 for applying said first and second frequency domain transforms use a transform selected
3 from the group consisting of discrete Fourier transforms, fast Fourier transforms, Goertzel
4 transforms, and discrete cosine transforms.

1 25. The dynamic range compressor of claim 17, further comprising:
2 an input transducer, said input transducer converting audio input signals to
3 analog input signals; and
4 an analog-to-digital converter, said analog-to-digital converter converting
5 said analog input signals to said digital input signals.

1 26. The dynamic range compressor of claim 17, further comprising:
2 a digital-to-analog converter, said digital-to-analog converter converting
3 said digital output signals to analog output signals; and
4 an output transducer, said output transducer converting said analog output
5 signals to an audio output.

1 27. The hearing aid of claim 17, wherein said windowing means
2 provides a 50 percent overlap of said first and second pluralities of frequency domain
3 level estimates.

1 28. The hearing aid of claim 17, wherein a quantity of samples
2 corresponding to said first block of said digital input signals is equivalent to a quantity of
3 first order all-pass filters corresponding to said plurality of cascaded all-pass filters.

1 29. The hearing aid of claim 28, wherein said first portion of said first
2 sequence of delayed samples is comprised of a first half of said first sequence of delayed
3 samples and said second portion of said first sequence of delayed samples is comprised of
4 a second half of said first sequence of delayed samples.

1 30. A hearing aid, comprising:
2 an input signal channel providing digital input signals;
3 an input data buffer, said input data buffer holding a block of data of size
4 M comprised of a portion of said digital input signals;
5 a plurality of cascaded all-pass filters comprised of 2M cascaded all-pass
6 filters, wherein a first block of said digital input signals pass from said input data buffer
7 through said plurality of cascaded all-pass filters to form a first sequence of delayed
8 samples and wherein a second block of said digital input signals pass from said input data
9 buffer through said plurality of cascaded all-pass filters to form a second sequence of
10 delayed samples, and wherein said first sequence of delayed samples and said second
11 sequence of delayed samples form a combined sequence of delayed samples;
12 means for windowing a first portion of said combined sequence of delayed
13 samples, wherein said first portion is of size M, wherein a windowed sequence of delayed
14 samples results from said windowing means;
15 means for applying a 2M-point frequency domain transform on said
16 windowed sequence of delayed samples, wherein a warped sequence results from said
17 frequency domain transform applying means;
18 means for calculating a plurality of frequency domain level estimates of
19 said warped sequence;
20 means for calculating a plurality of frequency domain gain coefficients
21 from said plurality of frequency domain level estimates;

22 means for applying an inverse frequency domain transform on said
23 plurality of frequency domain gain coefficients, wherein a set of compression filter
24 coefficients of a compression gain filter result from said inverse frequency domain
25 transform applying means; and
26 means for convolving a second portion of said combined sequence of
27 delayed samples with said compression filter coefficients, wherein said second portion is
28 of size M, wherein a digital output signal results from said convolving means.

1 31. The dynamic range compressor of claim 30, further comprising a
2 hearing aid, wherein the dynamic range compressor is incorporated within said hearing
3 aid.

1 32. The dynamic range compressor of claim 30, wherein said plurality
2 of frequency domain gain coefficients comprise a warped time-domain filter.

1 33. The dynamic range compressor of claim 30, further comprising a
2 digital-to-analog converter, said digital-to-analog converter converting said digital output
3 signals to analog output signals.

1 34. The dynamic range compressor of claim 33, further comprising an
2 output transducer, said output transducer converting said analog output signals to an
3 audio output.

1 35. The dynamic range compressor of claim 30, said plurality of
2 cascaded all-pass filters comprising a plurality of first order all-pass filters.

1 36. The dynamic range compressor of claim 30, further comprising a
2 digital processor, wherein said digital processor is adapted to provide said windowing
3 means, said means for applying said 2M-point frequency domain transform, said means
4 for calculating said plurality of frequency domain level estimates, said frequency domain
5 gain coefficients calculating means, said inverse frequency domain transform applying
6 means, and said convolving means.

1 37. The dynamic range compressor of claim 30, wherein said means
2 for applying said frequency domain transform uses a transform selected from the group

3 consisting of discrete Fourier transforms, fast Fourier transforms, Goertzel transforms,
4 and discrete cosine transforms.

1 38. The dynamic range compressor of claim 30, further comprising:
2 an input transducer, said input transducer converting audio input signals to
3 analog input signals; and
4 an analog-to-digital converter, said analog-to-digital converter converting
5 said analog input signals to said digital input signals.

1 39. The dynamic range compressor of claim 30, further comprising:
2 a digital-to-analog converter, said digital-to-analog converter converting
3 said digital output signals to analog output signals; and
4 an output transducer, said output transducer converting said analog output
5 signals to an audio output.

1 40. A method of processing sound in a hearing aid, comprising the
2 steps of:
3 receiving digital input signals;
4 passing a portion of said digital input signals through a plurality of
5 cascaded all-pass filters to form a sequence of delayed samples;
6 windowing said sequence of delayed samples;
7 applying a frequency domain transform to said windowed sequence of
8 delayed samples to form a warped sequence;
9 calculating a plurality of frequency domain level estimates from said
10 warped sequence;
11 calculating a plurality of frequency domain gain coefficients from said
12 plurality of frequency domain level estimates to form a warped time domain filter;
13 applying an inverse frequency domain transform on said plurality of
14 frequency domain gain coefficients to form a set of compression filter coefficients; and
15 convolving said sequence of delayed samples with said compression filter
16 coefficients to form a digital output signal.